

Impact of Chemistry and Process Kit Characteristics on Etch Rate Non-Uniformities in Pattern Transfer

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Abstract

Pattern transfer with processes dominated by physical ion bombardment exhibit non-uniformities which are typically by an order of magnitude higher than chemical etching processes for which the reactors used were designed and developed. The present experiments show that an understanding of the origin of high etch rate non-uniformities in such processes and a suitable characterization of the process kit used by a process kit factor, allowed systematic hardware modifications which finally resulted in a substantial reduction of the non-uniformities.

Introduction

Patterning of the films involved in the fabrication of high- k (e. g. Pt-BST-Pt) or ferroelectric (e. g. Pt-SBT-Pt) capacitors has been resulting in etch rate non-uniformities significantly higher ($\approx 30\%$) than those usually seen in silicon process technology. High non-uniformities require long overetches and as such patterning processes have to be performed repetitively for fabrication of storage capacitors, build-up of severe topography is inevitable; this in turn strongly complicates further processing and/or requires sumptuary planarization. The present experiments show that etch rate non-uniformities decrease as chemistry comes into play and that processes where pattern transfer is completely due to sputter erosion can be performed with acceptable non-uniformity after hardware modifications.

Experimental

All experiments were performed in an MERIE metal etcher using the standard process kit. The temperature of the reactor i. e. of both the chamber lid and the chamber wall was set to 90°C . All processes were magnetic field assisted. In the reactor chamber the wafer was mechanically clamped. Binary mixtures of the feed gases (Cl_2 , Ar, O_2) were used for processing 150mm diameter wafers.

Results and Discussion

Patterning of BST and SBT in O_2 and Ar rich plasmas and patterning of Pt (at temperatures up to 90°C) in all mixtures (0...100%) of these feed gases with Cl_2 resulted in very high non-uniformities ($\approx 30\%$). With increasing fraction of Cl_2 , only the non-uniformities obtained for BST and SBT decreased (down to $\approx 10\%$ in Cl_2 only plasmas) indicating formation of etch products (TiCl_x , TaCl_x). For the same reasons exposing resist (mask) and SiO_2 (underlayer) to such plasmas resulted in a decrease of the non-uniformity from 25% to 2% and from 35% to 25%, respectively, as etch products (CCl_x , SiCl_x) may be formed more or less efficiently. This interpretation is supported by the finding that high non-uniformities (30%) obtained for Pt patterning with reactor temperatures up to 90°C could be brought down to less than 10% when operating the etch system at elevated temperatures (300°C) where Pt is supposed to be chemically etched, forming volatile etch products. To achieve low non-uniformities of pattern transfer in Pt with Ar only plasmas is desirable because this allows fabrication of storage

nodes with vertical sidewalls and minimum CD change /1/. Generally, the higher net erosion rate in the wafer center and the observation that the erosion rate displayed radial symmetry i. e. did not vary notably around the wafer, were attributed to a higher rate of redeposition at the wafer edge from material of the process kit surrounding the wafer. Therefore a process kit factor was introduced which characterizes both the material and the geometry of the process kit. The process kit factor of a process kit is low when the material of choice exhibits high sputter yield and/or when the geometry/shape facilitates the redeposition of sputtered material onto the wafer; i.e. for process kits which reach close to the wafer edge and/or which protrude above the surface of the wafer. The improvement of the etch rate non-uniformity in patterning of Pt, which is physically dominated at $T < 90^\circ\text{C}$, was monitored by processing blanket oxide wafers. By modifications of the shape of the process kit, while leaving the material of the process kit unchanged, the process kit factor was continually increased. This implied a substantial decrease (30% \rightarrow 10%) of the etch rate non-uniformity, as expected, for all Cl_2/Ar mixed RF plasmas (0...100%) investigated. This decrease of non-uniformity was mainly due to an increase of the net etch/erosion rate at the edge of the wafer, which in turn is indicative of a decrease of redeposition of sputtered material from the process kit onto the wafer (edge).

Similar mechanisms were found to be effective in highly selective single crystal silicon etching with an SiO_2 hard mask, where the very same process (feed gases: HBr , NF_3 , He/O_2) results in still higher non-uniformities for the net oxide erosion/deposition on blanket SiO_2 wafers than on wafers with opened SiO_2 hard mask /2/; on blanket oxide wafers the oxide deposition is determined by the low-rate (non-uniform) redeposition of sputtered oxide from the film on the wafer, whereas on wafers with patterned mask it is determined by high-rate (highly uniform) etching of single crystal silicon, forming etch products /3/ which finally react with feed gases (NF_3 , O_2) to enable relatively uniform deposition of oxide. In this case, redepositions of the hard mask itself rather than material from the process kit is involved, in particular as etching of single crystal silicon is by far less dominated by ion bombardment than Pt patterning.

Conclusion

The present results show that characterization of the process kit by a process kit factor allows significant reduction of the non-uniformity of pattern transfer in physically dominated processes by modifications of the hardware as demonstrated for patterning of Pt at $T < 90^\circ\text{C}$. This is important for all applications where chemistry cannot be brought into play by feed gases or by processing at elevated temperatures.

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References

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